

## Fabrication of Robust, Flat, Thinned, UV-Imaging CCDs

**Front-side silicon substrates ensure flatness and provide strength.**

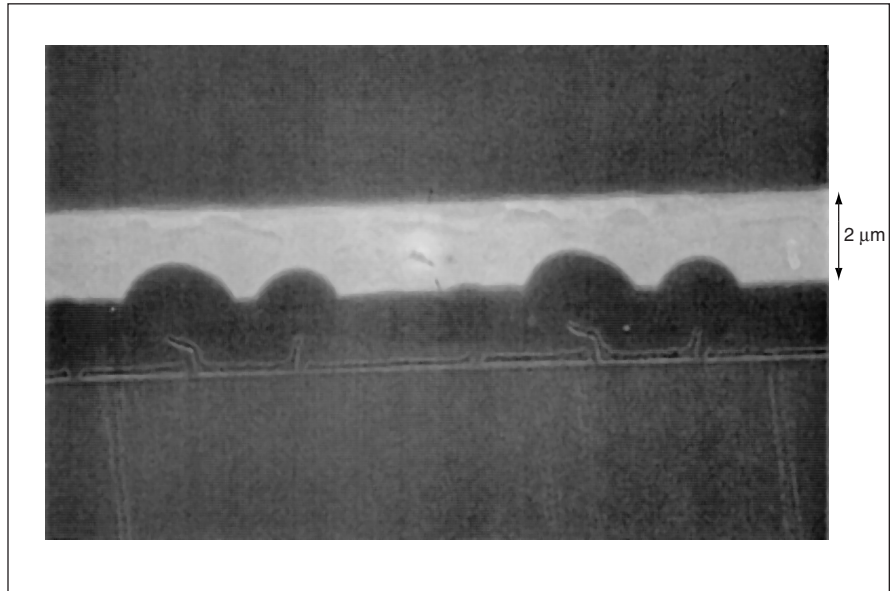
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An improved process that includes a high-temperature bonding subprocess has been developed to enable the fabrication of robust, flat, silicon-based charge-coupled devices (CCDs) for imaging in ultraviolet (UV) light and/or for detecting low-energy charged particles. The CCDs in question are devices on which CCD circuitry has already been formed and have been thinned for back-surface illumination. These CCDs may be delta doped, and aspects of this type of CCD have been described in several prior articles in *NASA Tech Briefs*. Unlike prior low-temperature bonding subprocesses based on the use of epoxies or waxes, the high-temperature bonding subprocess is compatible with the delta-doping process as well as with other CCD-fabrication processes.

The present improved process and its bonding, thinning, and delta-doping subprocesses, are characterized as post-fabrication processes because they are undertaken after the fabrication of CCD circuitry on the front side of a full-thickness silicon substrate. In a typical case, it is necessary to reduce the thickness of the CCD to between 10 and 20  $\mu\text{m}$  in order to take advantage of back-side illumination and in order to perform delta doping and/or other back-side treatment to enhance the quantum efficiency.

In the prior approach to the fabrication of back-side-illuminated CCDs, the thinning subprocess turned each CCD into a free-standing membrane that was fragile and tended to become wrinkled. In the present improved process, prior to thinning and delta doping, a CCD is bonded on its front side to a silicon substrate that has been prefabricated to include cutouts to accommodate subsequent electrical connections to bonding pads on the CCD circuitry. The substrate provides structural support to increase ruggedness and maintain flatness.

At the beginning of this process, the back side of a CCD as fabricated on a full-thickness substrate is polished. Silicon nitride is deposited on the back side, opposite the bonding pads on the



This **Scanning Electron Micrograph** depicts a cross section of the bond between a CCD and a silicon substrate. The bond is approximately 2  $\mu\text{m}$  thick.

front side, in order to define a relatively thick frame. The portion of the CCD not covered by the frame is the portion to be thinned by etching.

Trilayers of titanium, platinum, and gold are deposited by evaporation on the front side of the CCD and on the mating surface of the matched silicon substrate, in preparation for joining the CCD to the substrate by gold-gold thermocompression bonding. The platinum layers act as barriers to the diffusion of gold into the CCD (necessary because contamination by gold would degrade the performance of the CCD). The titanium layer increases the adhesion of the platinum layer to a protective oxide layer on the CCD. The gold layers on the CCD and the substrate are 1  $\mu\text{m}$  thick. Thermocompression bonding of the CCD and the silicon substrate is performed by heating the assembly to a temperature of 400  $^{\circ}\text{C}$  in a vacuum at a clamping pressure of 10 MPa for 30 minutes. The total gold thickness of 2  $\mu\text{m}$  is sufficient to fill the empty spaces between the CCD pixels and the silicon substrate (see figure).

The CCD-and-substrate unit is placed

back-side up in a fixture, wherein etching by a hot aqueous solution of KOH is performed to reduce the CCD thickness. After etching, the unit is cleaned, then transferred to another fixture that is placed in the ultra-high-vacuum chamber of a molecular-beam-epitaxy apparatus, wherein the delta doping is performed. Finally, the CCD is packaged and wire bonded.

*This work was done by Paula Grunthaner, Stythe Elliott, Todd Jones, and Shouleh Nikzad of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

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